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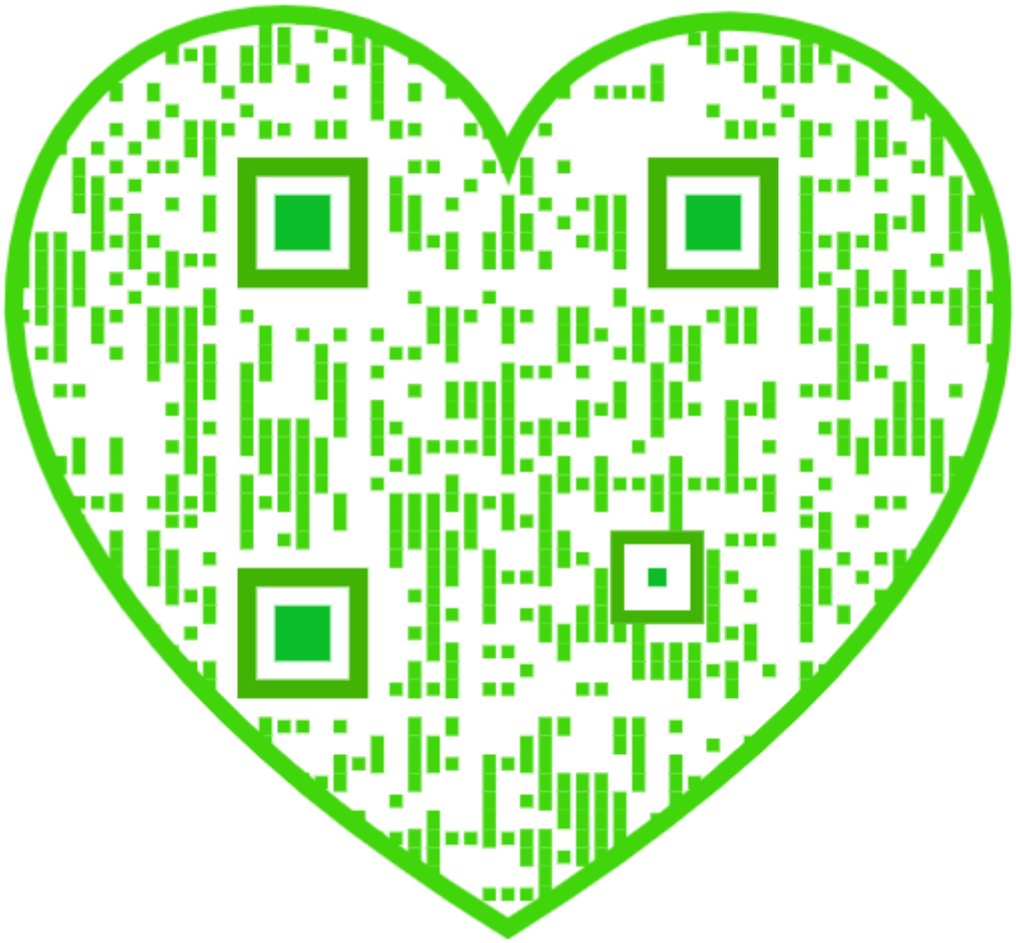

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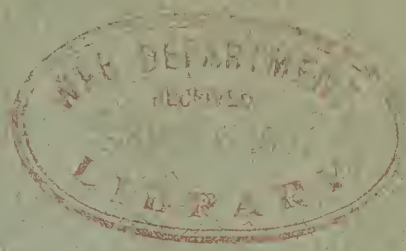

THE STORAGE OF ELECTRICAL ENERGY,

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11 N. Second St.,
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STORING ELECTRICAL ENERGY.

Some of the phenomena of electricity attracted observation from the earliest period. In 1671 Otto Guericke made an electrical machine with a globe of sulphur to be excited. This was the first form ever made. A sphere of glass was afterwards introduced, then a cylinder of glass, and finally a round glass plate, which was rubbed with dry silk.

In the year 1745 Prof. Muschenbroek, of Leyden, conceived of the idea of collecting and confining the sparks of this electrical machine. He employed a large glass jar nearly full of water, with a long iron rod penetrating through the cork into the water. The object he contemplated was partly accomplished, but the accumulation of electricity was not manifested owing to the want of an outside conducting surface.

Like many discoveries, the perfecting of the Leyden jar was the result of accident; for one of the pupils by the name of Cuenus, in a subsequent experiment, grasped the jar to hold it while disconnecting the rod from the electrical machine; his hand, serving for the outside coating, gave the desired effect, and this student in the new field of science received a stunning shock. Without disclosing his experience, and with a degree of forethought worthy of a better motive, he repeated the experiment upon Prof. Muschenbroek so successfully that he did not recover from the effects for several days.

We may store up electrical energy of very high potential in the Leyden jar and make use of it at intervals instead of taking it continuously from the machine, but the potential of the jar cannot be made to equal that of the charging machine.

It is a fact deserving consideration, that the accumulation of electricity by the Leyden jar increases the quantity effect, and diminishes the intensity of the electricity accumulated.

As the Leyden jar serves to increase the discharge without prolonging its effect it is not usually considered under the head of electrical storage of this age of electricity. It has the property of producing secondary currents in an induction apparatus when discharged through the primary coil. With a strong charge this secondary current may be caused to melt a foot of platinum wire. And alone or in connection with its induced effects will no doubt play an important part in the storage of electrical energy in the future.

In the year 1762, M. Sulzer noticed the electric current which is occasioned by a piece of lead and a piece of silver in contact with each other and with the tongue, and he thought that this effect was due to a solution of the metals. This may be considered the earliest mention of chemical action in the production of electricity, with which we have largely to deal in considering the storage of electrical energy.

This very simple experiment was repeated by the philosophers throughout Europe; was made the subject of lengthy discussions, and long after referred to in defense of the famous "contact force" which Volta and his followers considered to be the urging power of the Voltaic current.

In the year 1790 Paetz and Van Troostnick decomposed water into its constituent gases by passing electric sparks through water from gold electrodes.

In 1791, Galvani discovered that convulsions were produced by establishing a communication between the nerves and muscles of a frog's legs, by means of metals; thus laying the foundation from which the Galvanic battery afterwards sprung.

In 1799 Fabroni, disclosed the fact that the phenomena of galvanism originated from the action of chemical affinities.

In the year 1800, Volta, Professor of Natural Philosophy at Parvia, in a letter to the Royal Society, dated March 20th, announced the discovery of the uoltaic pile, now known as the galvanic battery. The first form of this battery consisted of silver and zinc disks separated by moistened cardboard, the silver, zinc, and cardboard being placed in series and wet with salt water.

The pile devised by Volta owed its origin to the interpretation which this philosopher gave to the remarkable experiment, by Galvani, namely, that a frog's legs undergoes commotion when contact is made between the nerves and muscles by metals.

Volta had previously added to the apparatus of the electrician what is known as an electrophorus, an apparatus exemplifying in a remarkably striking manner the action of induced electricity.

The researches of Lavoisier, La Place, and Fabroni, relative to electrical excitement by evaporation of fluids, by the solution of solids in acids, by every instance of sudden change of state, and of rapid chemical action, had indicated the close connection between electricity and chemical action, which proved of important bearing in the development of Volta's pile.

It may be easily believed that Volta was influenced in his discovery by the study of the electric torpedo, as he called his apparatus an artificial electrical organ (organe electrique artificile).

Although the discoveries of Volta were far surpassing in importance those by Galvani, they were at first considered merely subservient to the purpose of giving greater effect to the experiments of the latter, and because the battery of Volta was chiefly employed to illustrate the discovery of Galvani; it received the name of galvanic

battery, and the new branch of science founded upon it is termed galvanism.

Numerous attempts were made, after the announcement of Volta's invention, to improve the form and action of the apparatus. These endeavors have been continued, with more or less success, to the present day, of which the storage of electrical energy is an instance, for, as will be shown, the accumulator is but a galvanic battery.

Two months after the announcement by Volta of his invention, Messsrs. Nicholson and Carlisle decomposed water into its constituent gases by means of Volta's pile.

In 1801, Dr. Wollaston pronounced that the oxidation of the metals in a voltaic pile is the cause of its electrical effects; later in the same year, he turned the power of an electrical machine into a continuous current while decomposing water by frictional electricity. This is the first recorded account of secondary effects of a continuous character.

In 1801, Gautherot observed the action due to polarization on which electrical storage is supposed to depend.

In 1802, in the very infancy of voltaic electricity, an *artificial magnet* was employed to decompose water in place of the direct galvanic or voltaic current. This is of interest in connection with the employment of magneto-electricity in charging accumulators.

In 1803, Ritter of Jena devised a secondary battery making use of the currents due to polarization. When an electric current is sent through acidulated water, with platinum plates as electrodes, a film of oxygen covers the positive electrode, and a film of hydrogen covers the negative electrode. One of these two substances being electro-positive and the other electro-negative, they act in the liquid like two different metals; the hydrogen plays the part of zinc, and the oxygen plays the part of platinum.

Withdrawing the charging battery and connecting the two plates thus covered with films of gas, by a conducting

wire, an electric current is obtained. The direction of this current is from the hydrogen film to the oxygen film through the conducting wire.

Two electrodes thus covered with condensed gaseous films are said to be polarized.

When a cell with platinum plates is introduced into a voltaic circuit it is found that the battery-current, though strong at first, gradually weakens. This is due to the opposed current of polarization.

The electro-motive force of the film-covered plates is in the opposite direction from the current charging them, and may be far greater than that of the battery charging them. It may give a more brilliant spark and overcome resistances insuperable to the charging battery.

This form of battery was discovered by Ritter. Some writers accredit the invention to Gautherot in 1801, as consisting of a phial containing salt and water, with a stopper through which passed two silver wires. Gautherot was followed by Erman, a German, who was in turn followed by Ritter of Jena.

In 1805, Brugnatelli deposited gold on silver medals by voltaic action by immersing them in ammonurate of gold.

In 1812, Zamboni constructed a pile of alternate layers of tin foil, paper and peroxide of manganees.

In 1826, Nobili, by the electrolysis of a solution of the acetate of lead, deposited peroxide of lead on plates of metal.

In 1833, Faraday set the whole theory of storage of electrical energy on a firm basis in a series of papers communicated to the Royal Society. He said that "the decomposing action of a current is constant for a constant quantity of electricity, notwithstanding great variations in its sources, in its intensities or in other circumstances. He showed by numerous experiments that electricity and chemical affinity are the same force differently modified; by showing that the amount of decomposing effects in all substances agrees with their chemical equivalents.

To those not acquainted with the nature of chemical combinations it may be desirable to state that the elements of bodies always unite in definite proportions. For instance, eight atoms of oxygen unite with one of hydrogen to form water, and one atom of oxygen unites with five of potassium to form potass.

The eight parts of oxygen which combine with one of hydrogen to form water combine in the proportions of 32 with copper, 58 with tin and 103 with lead; and the same amount of electric force that is required to separate 8 parts of oxygen from water will, by secondary action, separate copper, tin and lead from their combinations with oxygen in the proportion of 32 with copper, 58 with tin and 103 with lead.

Faraday carefully collected the results of the action of a zinc plate and a plate of platinum in dilute acid.

The quantity of oxygen and hydrogen evolved showed the amount of water decomposed. The weight of the zinc plate was diminished, and the weight of water decomposed, as 9 is to 32.31; these numbers correspond with the equivalents of water and zinc.

In 1837, Schonbien, of Basle, announced the fact that plates coated with peroxide of lead possessed electro-motive qualities.

In 1839, Dr. Golding Bird announced the fact that a platinum plate coupled with a zinc plate immersed in acidulated water, and polarized by galvanic action, evolved hydrogen in unequal proportions.

In 1840, Murray deposited various metals on carbon surfaces by galvanic action.

In 1841, Alfred Smee enunciated the laws regulating the character of metallic deposits by galvanic action.

In 1842, Grove invented his gas battery. This arrangement consisted of platinized plates enclosed in tubes, and arranged in pairs. One plate of each pair being surrounded with oxygen gas and the other with hydrogen

gas, the lower extremities of the plates being in acidulated water.

The gases in the tubes were formed by passing a galvanic current through the pair. The gases forming at each plate in well-known proportions. The battery being disconnected and the plates connected by a wire, a continuous current is produced exceeding that of a Daniels element in electro-motive force. The current continuing to flow until the gases previously accumulated have recombined.

The current produced by the Grove gas battery is equal to the current which produced the gases by the decomposition of the acidulated water. A modification of this battery, affording greater surface of triple contact between metal, gases and acidulated water, promises the best of any form of storage battery for many uses.

In subsequent experiments Mr. Grove employed plates covered with peroxides of metals, and C. W. Siemens employed carbon tubes, very porous. The carbon gave a greater quantitive effect, with less intensity. The intensity was increased by coating the tubes by galvanic deposition of platinum before introducing them for charging.

In 1843, Wheatstone constructed what he was pleased to term a *galvanic* battery which employed platinum plates coated with peroxide of lead in conjunction with amalgam of potassium ; in describing the same, he says, "such a plate is easily prepared by making it the positive electrode in a decomposing cell charged with a solution of acetate of lead."

In 1852, C. W. Siemens constructed a secondary battery by employing carbon plates impregnated and coated with peroxide of lead, in acidulated water ; describing it he says : "The plates were dipped into a solution of acetate of lead. Then heated to dull redness, cooled, and again dipped in the lead solution. After repeating this operation several times the plates were acted on by gal-

vanic currents by which the lead was converted into peroxide of lead. The current from the secondary battery thus formed gave two volts from a single pair. A larger battery of carbon plates thus coated and held separate by a porous partition gave good results."

The power of this form of cell depends upon the time of application as well as the power of the charging current. It affords a large amount of active surface in a small space, and is less expensive, and less weight than batteries employing lead plates.

In 1859, M. Gaston Plant showed that lead was the most favorable metal for use in secondary batteries and he has since then multiplied proof of this superiority.

In its first form the battery of Plante consisted of sheets of lead held separate by a sheet or strip of felt, and rolled together to form a cylindrical shape to fit the glass jar. This battery thus constructed was filled with acidulated water and the peroxide of lead formed on the plates by the slow action of a galvanic current.

In the first formation when the battery is new there is an advantage in polarizing the electrodes first in one direction and then in the other, and in reversing several times the direction of the charge, but in subsequent uses care hould be observed to always charge it in the same direction.

After the battery is " formed " the plates are found to be coated with an active layer of absorptive substance that will receive and discharge electricity.

The greater number of times a secondary battery is charged and discharged the better it is. Intervals of rest improve this form of battery.

He connected four or five elements or cells side by side, and charged them from three Bunsen elements, and connected them in series for discharging. The secondary currents are able to magnetize electro-magnets more powerfully than the primary currents from which they are derived.

It is found that when the resistance is considerable the current remains constant during several hours. It was found that a well "formed" element would give a good current several weeks after it was charged.

In order to obtain currents of great energy a number of secondary elements are arranged side by side, and charged and connected in series to be discharged.

As commonly understood, Plante's secondary batteries were constructed only in view of scientific researches ; he, nevertheless, used forms possessing industrial qualities. He employed the peroxide of lead as a cement or paste, pressed into spaces in a metal plate or electrode, in shape not unlike a gridiron.

In 1861, Charles Kirchhof described several modifications of secondary batteries. One of these batteries consisted of metal plates coated with mercury and immersed in acidulated water or in solutions of sulphate of copper. He describes another consisting of plates of metal coated with peroxide of lead and spongy lead, by electro deposition in a solution of nitrate and acetate of lead. He describes using lead plates coated with mercury, and says: "Electricity from any source may be stored up, as, for instance, connecting these forms of batteries between a lightning rod and the earth to obtain atmospheric electricity, or with a rubber of a frictional machine, or with a magneto electrical machine."

In 1866, Geo. G. Percival employed electrodes for secondary batteries, consisting of metal plates covered with crushed coke and powdered lead, in diluted sulphuric acid.

In 1869, Mr. Percival published a description of an improved form of secondary battery consisting of a positive electrode of zinc, with a neutral solution of the positive metal as—Zn. So. 4. By this means not only is peroxide of lead deposited on the negative electrode, but there is also a finely divided deposit of zinc on the positive electrode, and sulphuric acid is liberated.

By this arrangement a much more energetic chemical, and consequently electrical action is developed, when the charging current ceases, than if both electrodes were of lead. He amalgamates the zincs.

In 1872, Deschanel, of Paris, employed a secondary battery consisting of electrodes coated with metallic salts, mechanically applied.

He describes two electrodes coated by electro deposition, but says: "It is not necessary that the deposition of the substances on the plates should have been brought about by electrolysis. A similar result will be obtained if the plates be coated with the substances in any other way."

In 1879, Count d'Arsonval employed carbon plates covered by oxides of lead and manganese, coupled with zinc plates in solution of sulphate of zinc.

It will appear from the foregoing that a secondary battery can be formed by the use of gases in the presence of unoxidized electrodes, preferably of platinum or carbon:

By electrodes of different character, whether of different metals or of the same metals, surrounded or coated with electrolytes of different character, or ;

By electrodes of different chemical potential, made so by galvanic action.

It has been shown in the foregoing that secondary batterries have been used with electrodes coated with an active layer of absorptive substance, such as metal or metallic compound that becomes spongy and thus capable of receiving and discharging electricity, that the electrodes have frequently consisted of plates impregnated, and coated, with oxides, insoluble salts, and amalgams of metals applied as a paste, by electro deposition or, otherwise.

The electricity received into secondary batteries is not retained as electricity, but is held in a chemical embrace and gives out the electrical discharge by the action or chemical affinities as disclosed by Fabroni in 1799. They

are a galvanic battery that can be recombined by electrical currents when it has become exhausted.

In 1882, a patent was granted to Camille A. Faure, a native of France, for a polarization or secondary electric battery. (No. 252,002.)

The invention is alleged to consist in "the addition or application of a layer of active material—as a metal, metallic oxide or salt—to suitable plates, and that this active material may be applied in various ways, as in the form of paint, paste or cement, in the form of a deposit by galvanic action, or chemical precipitation, or otherwise."

The process of "forming" this battery is not unlike that practised by Plante and others and the electrolytic liquid the same.

The salts of lead not soluble in the electrolytic liquid are preferred, but the invention is not limited to these, but includes generally substances capable of storing electrical energy.

The claim for this form of secondary battery, is: "As an improvement in secondary batteries, an electrode consisting of a support coated on one or more faces with an active layer of absorptive substance—such as metal or metallic compound applied thereto in the described condition so as to or instantly become spongy, and thus capable of receiving and discharging electricity, as stated, in contradistinction to a metallic plate itself rendered spongy by the disintregating action of electricity."

There are other claims for sub-combinations.

Public interest was aroused to a high degree by statements published in leading papers in May, 1881, regarding results which had been obtained from a secondary battery constructed by Faure, which occupied less than a cubic foot of space and was charged by an ordinary Grove battery.

If this battery proves to be as effective as was then claimed for it, the superiority is due to care in construction, and to a painstaking and prolonged process of "form-

ing," with powerful currents, rather than to any novelty involved or arrangement of parts that amounts to discovery.

It does not obviate the long continued process of "forming." A portion of its interior, the felt sheathing, is destroyed by the acid, besides this form of battery is too heavy for portable uses.

To convey a true impression of its capabilities it may be stated that the results derived from experiments by the official commission of the Electrical Exhibition at Paris demonstrates that 35 cells, each weighing 96¼ pounds, with liquid and containing vessel included, gave one-horse power for one hour for each 238 pounds of battery.

This is but little better than the earlier forms of Plante's secondary batteries are said to have afforded.

In all the foregoing described forms of secondary batteries, the electricity that is used to charge them, passes through them and does not accumulate in the battery as some might suppose, but in passing through the battery it acts to create a difference in chemical potential between the positive and negative plates which constitute the battery, and when these plates are fully charged in their chemical relations to each other, and the charging current has ceased to flow, these batteries are then simply galvanic batteries, and in the act of being discharged they lose their power like other galvanic batteries, but they can be charged whenever exhausted by the action of electricity passed through them, and do not consume zinc and chemicals which require to be replenished.

Galvanic batteries which consume zinc and chemicals give electricity in abundance, and if they had continued to be the principal mode of supplying electricity we should not have so much need of secondary batteries, as it would be as well to employ these batteries direct as to store their energy.

But chemical consuming galvanic batteries are too expensive for producing light and power.

The development of Faraday's discovery that the motion of a coil of wire in front of the poles of a magnet or in a magnetic field gives rise to an electric current in the wire, has shown us that the burning of zinc or other materials in batteries such as Grove's or Daniell's, is a very expensive way of producing an electric current, and that it is far more economical to obtain electric currents by employing the best mechanical means we have to produce rotation of the coil of wire in the magnetic field. The different magneto and dynamo-electric machines (and they abound) are but the results of attempts to find the best form of coil, the best kind and best form of magnets, the best proportion of resistances, and the most suitable arrangements for the special work in each case which is required to be done. The dynamo-electric machine is very satisfactory as a mode of producing electricity, and both the electromotive force and the current increase with the rate of rotation of the coil. This mode of producing electricity is like raising water to any level that may be required in each particular case ; but the electricity must be used at once. This may be very inconvenient, and hence the necessity for something like a reservoir to store up the electricity. The labors of Faraday have shown us the relation between the quantity of electricity and the weights of the chemical elements decomposed by it in an electrolyte, and that these chemical elements may unite again to reproduce the same quantity of electricity. The object, then, to attain by means of secondary batteries is to find some substance which can be decomposed into two others which will remain apart, even when joined by a liquid conductor, until a complete electric circuit is made. Then these two substances should be at considerable difference of potential, so as to give a strong electrlc current in

uniting again to form the substance from which they were decomposed.

Besides those secondary batteries previously described, convenient forms are had by employing a scroll of copper and a scroll of zinc, arranged as in a gravity battery, in a solution of sulphate of zinc, or—

By employing plates of lead, dish shaped, filled with red oxide of lead, or peroxide of manganese, covered with cloth or like porous layer, and set one on to the other; a dilute solution of vinegar or sulphuric acid can be used. A secondary battery employing a negative plate of palladium which during the action of electrolysis absorbs more than 900 times its volume of hydrogen with a positive pole of lead, is well spoken of. Good results are said to have been obtained by the use of iron turnings in place of the palladium plate, as it will absorb 200 times its volume of hydrogen in a solution of sulphate of ammonia of 50 per cent. of salt.

The negative electrode should have the property of absorbing hydrogen, and the positive pole should have the property of absorbing oxygen or of becoming peroxidized.

The decomposition of alkalies does not require a powerful voltaic arrangement Iodide of potassium may be decomposed by a single pair of plates feebly charged, but for producing decomposition in most solutions not less than three cells of battery should be employed.

The decomposing power of a ray of light upon one of a pair of iodized silver plates, immersed in water, in the dark, will cause a galvanometer to be deflected. The plate upon which the light falls becoming positive.

A self-charging secondary battery was made by Prof. Grove in 1845, and is described as follows: "The glass cells to contain the acid water are open; the hydrogen tubes, of which one is in each cell, all enter a common glass tube, which is above them, like the hydraulic main in a gas work; one end of this tube is closed, and the

other is connected with a generator of hydrogen similar to that of Dobereiner's apparatus ; by this means the supply of hydrogen is constantly maintained. The platinized plates are in each tube, and other plates, properly connected, are immersed in the acid liquid of the cells, which being exposed to air, keeps up the supply of oxygen. Mr. Grove's experiments show that the most invariable action can be relied on for years."

A self-charging apparatus is described in Il Cimento, Ann. iii, 1845, as follows: "M. Marianini took five Leyden jars coated with zinc outside and with silver inside; he placed them one within the other, and made communication between the inner coating of the innermost and the outer of the outermost, by means of a silver wire, and the apparatus charged itself. His test of charge was the contraction of a frog placed in the circuit."

The galvanic battery, and in fact the whole science of galvanism, reverts for its origin to the interpretation which Prof. Volta placed upon the simple, labratory experiment by Galvani, and the republication of the experiments by Grove and Marianini in this age of practical application of every means for producing and utilizing currents, may lead to the construction of a self-charging pile that will actuate clocks, or serve for occasional ringing of bells, like open circuit batteries.

Charles Kirchhof, previously referred to, states that electrical energy may be stored from friction machines, and by connecting easily charged batteries between a lightning rod and the earth.

In a letter written by Prof. Winthrop, of Cambridge, Mass., to Benj. Franklin, bearing date September 29 1762, he says: "There is an observation relating to electricity in the atmosphere which seemed new to me. I have some points on the top of my house, and the wire where it passes withinside the house is furnished with

bells, according to your method, to give notice of the passage of electric fluid. In summer these bells ring at the approach of a thunder storm, but cease soon after it begins to rain; in winter they sometimes, though not very often, ring while it is snowing, but never, as I remember, when it rains. But what was unexpected to me was, that, though the bells had not rung while it was snowing, yet the next day, after it had done snowing, and the weather had cleared up, while the snow was driven about by a high wind, west or northwest, the bells rung for several hours as briskly as I had ever known them, and I drew considerable sparks from the wire."

The action described by Prof. Winthrop would seem to be too intermittent to be utilized, but constant currents may be obtained from plates of copper and zinc, or iron, buried in the earth, the effect from which might be supplemented by the atmospheric currents, which are nearly always present and sometimes intense, as during what are termed magnetic storms.

The constant product from belts and machinery in factories can, without doubt, be utilized, and a waste product turned to account for lighting the factory, or adjacent buildings, or for other obvious uses.

The constant discharge of electricity from the belt can be passed into secondary batteries containing an easily decomposed electrolyte, or the sparks can be first accumulated in a Leyden jar, and sent with more quantity effect into the secondary batteries. While advantages might be gained by modifying the Leyden jar by making it resemble more nearly Marianini's apparatus, or an easily charged secondary battery; care should be taken to insulate the apparatus perfectly.

Twenty-eight secondary batteries of forty pounds weight each will maintain twenty incandescent lamps of eight candle power each for twenty hours. With forty such batteries ten incandescent lamps of twenty candle power

each can be maintained for ten hours. In the latter case an average of eight pounds of battery maintains a candle power of light for ten hours.

When the size of each battery is increased and the number of batteries remain the same a very much larger number of lamps can be maintained. Thirty-three cells of secondary battery, each weighing 300 pounds, sustained 201 twenty candle power lamps at their full capacity of incandescence. To light one such lamp properly would require the same degree of energy, or nearly so, but to light one such lamp would not require very large cells.

Lamps of low resistance and large light-giving surface can be made incandescent by a less number of cells of secondary battery, of large size.

It is possible to charge these batteries from a few cells of gravity battery, but to accomplish satisfactory results a dynamo machine is necessary, and the constant current dynamo-electric machines adapted for plating give good results.

A small Gramme machine of the A type, having an internal resistance of 4.58 ohms, and with an external resistance of 4 ohms, gives an electric current of 17.5 webers and an electro-motive force of 158.5 volts, giving an amount of work equivalent to 2 h. p.=8 times the energy of 40 cells of Grove.

If we wish to replace such a machine by Grove's cells, we should have to arrange about 80 cells to get the same electro-motive force, and to make each cell about four times as large, or to arrange 320 cells in four sets of 80 in each set, to get the same amount of external work done as by the Gramme machine. This will show how impossible it is to do the work by voltaic batteries which can be done by magneto-electric machines.

When a dynamo machine is used for charging, the machine should be placed in the circuit with the secondary batteries in a developed condition.

As it requires a brief interval of time for a machine to speed up and to build up a current in its field of force magnets, and, as as the secondary batteries, after having been used, retain a residual charge of no mean character, if the machine was connected into the circuit with these batteries before it had gained a proper speed, and before it was producing a current sufficient to charge the batteries, the residual charge in the batteries, acting instantly, would set up a current through the helices of the machine, and magnetize it in a wrong direction.

To overcome this difficulty the machine can be run on a developing circuit. Then the current from the machine can be split through the charging circuit which includes the secondary batteries, and then the developing circuit can be broken, and the machine be left in the charging circuit with the secondary batteries, producing a current that will not be overcome by the batteries.

This described manipulation of circuits can be accomplished, automatically, by a ball governor, or by an electromagnetic switch actuated by the current of the machine when it has become sufficiently powerful.

Another mode of overcoming the difficulty due to the retained charge of secondary batteries, is to divide the current from the dynamo machine, one portion passing through the helices of the field-of-force magnets, and another portion going to charge the secondary batteries.

Still another way of obviating the trouble is to charge the field-of-force magnets from an independent source of electricity.

By observing these precautions the irregular power of wind wheels, tide wheels and other like waste forces can be converted into electricity, and, by means of secondary batteries, transformed into a constant power of less force, or a greater power for a less period of time.

The current from the dynamo-electrical machine is unstable for small changes in the speed of the motor when

the product is less than two-thirds the capacity of the dynamo, the difference depending on the change of speed from 600 to 700 revolutions a minute, being from 5 to 15 units in the current in its decomposing effect.

It is impossible to fully realize the consequences that must follow from the combination of electrical storage of energy with the dynamo-electric machine. The dynamo-electric machine, standing alone and unsupported by electrical storage of energy, is truly a great power, largely tending to develop the practical use of electricity; but in alliance with the secondary voltaic action, in a perfected form of battery, the practical value of the dynamo-electric machine will be increased a hundred fold. Things that are impossible to be done with the unaided dynamo can be easily accomplished by this combination, coal could be burned at the mines and by engines, and dynamo machines be converted into electricity and transmitted over wires to the cities and be reconverted into available power-giving form by electrical storage.

Water powers that are remote from railways could be converted into such power on the line of railways. Such electric transmission of power is already feasible and the constant accumulation of a water power in secondary voltaic energy during twenty-four hours would exceed the power of the water during ten hours, after all deductions for loss were made, and the losses need not be large even over long distances.

Eminent electricians express themselves with confidence in this matter.

Sir W. Thomson showed, in his inaugural address last year to the British Association, that if it were desired to transmit 26,250 horse power by a copper wire half an inch in diameter, from Niagara to New York, which is about 300 miles distance, and not to lose more than one-fifth of the whole amount of work—that is, to deliver up in New York 21,000 horse power—the electromotive force be-

tween the two wires must be 80,000 volts. Now, what, asks Professor Ayrton, is to be done with this enormous electromotive force at the New York end of the wires?

The solution of this problem, he says, was also given by Sir W. Thomson on the same occasion, and it consists in using large numbers of accumulators. All that is necessary to do in order to subdivide this enormous electromotive into what may be called small commercial electromotive forces, is to keep a battery, of 40,000 cells, always charged direct from the main current, and to apply a methodical system of removing sets of 50 and placing them on the town supply circuits, while other sets of 50 are being regularly introduced into the main circuit that is being charged. Of course this removal does not mean bodily removal of the cells, but merely disconnecting the wires. It is probable that this employment of secondary batteries will be of great importance since it overcomes the last difficulty in the economical electrical transmission of power over long distances.

The political and social significance of the applications of electricity will increase as the development of systems of power and light by means of this agent are multiplied.

Electricity, unlike steam, does not necessitate the aggregation of capital. A steam engine can give power only within the range of its shafting. A dynamo electric machine propelled by water power could work a loom in every house and drive a plow on every farm for miles around.

In the cities they declare that one electric lamp is as effective as five policemen.

The type in Guttenberg's printing press in its mechanical combination proves more potent than political combinations.

It has been said that "steam blew up aristocracy," but a stronger agent than steam is at work to-day upon the social and political structure. The means of production are in the hands of the few now, but what promises to be

the motive force of the future will not belong to private owners.

The fitful but tremendous forces of nature by the agency of the dynamo machine and the storage battery will become the main spring of our light and power-giving systems of the future.

Probably the present storage battery bears as much resemblance to the the future accumulator, as the bladder which Dr. Clayton used as a gas holder in 1688 does to the gasometer of city gas works, or as James Watt's crude steam engine does to the Atlantic steamer. When the accumulator of the future has been built it will be more easy to say what the limit of its use will be, but at present we have to deal with less perfect forms.

For many uses, a secondary battery like the pile devised by Zamboni, in 1812, moistened with potash water, is a convenient form.

A secondary battery consisting of lead shot, coated with mercury, and contained in a porous cup, such as are used in ordinary galvanic batteries, with an outside glass, or copper jar filled with broken coke has been used, with good results. A conducting piece being surrounded by the shot, and another in contact with the coke to carry off the currents, are necessary.

A dense solution of sulphate of copper, without crystals, covers the coke. The shot in the porous cup being covered with acidulated water.

The charging current should always enter at the porous cup.

When the battery is fully charged the solution becomes clear, and when discharged becomes blue again.

A form similar in many respects to the above is described by Kirchhof and by Sutton.

Another form consisting of shot coated, or mixed with peroxide of lead, for either electrodes, gives good results, but requires a process of "forming."

The employment of shot affords a larger surface than the same weight of sheet lead, and has other advantages.

A secondary battery with plates or scrolls of metal, arranged as in the gravity battery, with a solution of sulphate of zinc, is well spoken of for some uses, but all these easily constructed forms are subject to local action, and lose some of their power, even upon an open circuit.

In making experiments with secondary batteries the greatest degree of patience is required, as it frequently takes a long time to "form" a battery so that it will receive a charge.

Those forms of batteries employing peroxide of lead require four or five hundred hours to be properly "formed."

The depolarization of the conducting electrodes in galvanic batteries is usually effected by oxygen, but it can also be done by chlorine and greater energy be obtained; chloride of platinum was employed by Daniell, chloride of silver by Marie Davy, Warren De La Rue and Gaiffe, chloride of lead by Davy, perchloride of iron by Derchemin and chloride of lime by the writer.

Chlorine is an easily produced gas, and it affords constancy of action, and great energy, and may be found available in secondary voltaic batteries.

The chloride of silver battery recently used by Warren De La Rue consisted of 14,600 cells, and gave wonderful results.

The battery consists of a zinc electrode unamalgamated, with an electrode formed of a cylinder of chloride of silver melted around a silver wire. The liquid is dilute sal ammoniac.

This form of battery was designed for experiments of short duration, but it is found to act without polarization during long uses; during its action zinc is substituted for

silver in the chloride; there is no hydrogen evolved and consequently no polarization.

This form of battery will last for years, and can be renewed by the recovery of the metals employed, so that the replenishing of material consumed would be trifling, but the expense of first construction is considerable.

A secondary battery involving the same action as the chloride of silver battery, with the absence of local or internal action as long as the circuit is open, would be a welcome addition to the list.

The constant and varied thought which is being given to this subject will certainly establish every fact in connection with the storage of electrical energy, and it is safe to predict that a perfect secondary battery will be produced.

The modes of charging are not as readily multiplied as the forms of batteries, because of the almost endless variations that can be made when dealing with chemical combinations.

The uses of secondary batteries, however, run out in so many directions that a field is open for inventors in the adaptation of this stored energy, to work out the variety of operations.

The delivery of electricity to residences, stores, and other buildings, in this stored form, and for all its many uses, has been the most desirable method of placing it before the public, as considered by many.

Others have contemplated the locating of suitable storage batteries, at each house or building, and by making daily visits with a portable dynamo-electric machine, charge the batteries, as they stand, with a requisite supply of energy for the work to be accomplished.

A better way, in most cases, would seem to be to have secondary batteries at each house or building, and to connect these several batteries with a dynamo-electric machine at a central or otherwise conveniently located point, and

to constantly charge them, or parts of them, by cheaply produced currents of low energy, which can be delivered over inexpensive conductors that may be buried in the earth without expensive insulation.

Circuits that are employed for the charging of batteries could be used for street lamps at night, and the batteries that had been charged over them, being disconnected, could furnish light for their respective buildings, or the circuits could be used to furnish power and also store energy at the same time, during the day, and then at night be used for street lighting, thus utilizing a not expensive plant of circuits and machinery for several uses.

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